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STRENGTH TESTS IN INDUSTRY.

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INTRODUCTORY.

For many years tests of muscular strength have been used by physical trainers and gymnasium directors, and more recently, to some extent, by physicians and teachers. The gymnasium director and the teacher find strength tests useful in showing the physical state of pupils at any given time, and their progress from time to time, whether this progress be due to special training or be simply the result of normal growth. Some physicians have used tests of strength as means of judging the condition of patients (Kellogg, 1896; Lovett, 1916).

This report describes the results of strength tests as applied to industrial workers. The field for such tests in industry is various. One result of the studies here described is the demonstration that different jobs have different "standard" strengths, and that operatives who are unable to measure up to the standard of strength for their jobs are not so likely to prove satisfactory in achievement and able to stand up under the strain of the work as those workers whose strength is equal to the demands upon it. From the standpoint of both employer and employee such information is valuable.

Variations of strength from day to day, as indicated by daily tests on the same individuals, are evidence of fluctuations in physical condition. Such fluctuations are important in so far as they affect the industrial efficiency of the worker. Studies of daily variations in strength should lead to information concerning the factors which influence the physical condition, and so the efficiency, from day to day.

Variations of strength between the beginning and the end of the working period, particularly if they take the direction of a falling off at the end of the shift, are indicative of an impairment of physique which can be most readily explained on the basis of fatigue. Improvement in condition during the day, as indicated by a better strength showing at the end of the shift than at the beginning, is not always easy to interpret; a slight increase appears to be normal. Probably in most cases a marked increase is referable to a poor state at the beginning, due to causes connected with the life of the worker outside the factory.

STRENGTH TESTS IN GENERAL.

Various methods have been used in the past for estimating the strength of human beings. Such simple schemes as lifting weights or testing the force of sledge blows have a certain value, although they have usually not found favor in the eyes of serious investigators. The earlier students of muscular strength depended most frequently on methods in which the strength is exercised in bending a stiff spring, and the degree of bending is observed. An apparatus suitable for tests of this kind is called a spring dynamometer. The type most widely used is the "grip" dynamometer of Collins. (For description see Whipple, 1914.) This instrument tests the strength of the grip, the muscles employed being the flexor muscles of the hand. An improved form designed by Smedley (described also by Whipple, 1914) obviates certain imperfections of the Collins instrument. Some gymnasiums have made tests with a spring dynamometer in which the force is applied by lifting upward against a spring which is fastened to the floor, thus testing the muscles of the back (Whipple, 1914).

All these spring dynamometers, in fact all strength tests hitherto in use, depend on positive efforts on the part of the subject; the person being tested exerts himself actively to make his record. The special feature of the test used in this series of studies is that it depends on the overcoming by another of the maximum resistance on the part of the subject. Instead of making a positive effort the subject, in this test, confines himself to resisting with all his power a pull exerted by some one else.

THE PRESENT TEST.

1. History.

In 1915 a strength test was designed by the writer to be used in determining the extent of muscular impairment in persons, chiefly children, afflicted with infantile paralysis. This was part of an extensive campaign carried on by the State Board of Health of Vermont, through the generosity of an anonymous donor, having for its object the alleviation of the condition of sufferers from that disease in that State. The scheme of requiring the subject to resist a pull applied by another was adopted primarily in the belief that actual strength could thus be more reliably determined in young children. In practice the scheme proved quickly to have so many advantages that it was thought worth recommending as a general method for strength testing. Continued experience has justified this idea, and the test in its present form, as described below (see also Martin and Rich, 1918), is presented as a thoroughly satisfactory means of measuring strength in children or adults, male or female.

For the original purpose of the test it was necessary to be able to examine as many muscle-groups as possible, since the impairment of strength in infantile paralysis may involve any or all parts of the body. As a matter of fact, 44 muscle-groups, 12 on each arm and 10 on each leg, were included. It was found impracticable to test muscles of the trunk or neck. The method of testing each of these 44 groups is described in detail in a paper by Lovett and Martin (1916) and will not be repeated here. The complete test, as used for the study of infantile paralysis, occupies between a half hour and an hour. For industrial purposes it is evident that any test that takes so much time is practically useless. The first requirement, therefore, is a shortening in the time consumed. In the winter of 1917–18 Martin and Rich (1918) examined carefully the possibilities of abbreviating the test by confining it to a part only of the muscle-groups, and computing from the strengths shown by these the value that would have been obtained had the entire series of muscle-groups been tested. They were able to demonstrate that such an abbreviation of the test gives valid results, hence the method as worked out by them was adopted for the present study. The "standard short test," as devised by Martin and Rich, is made up of tests of the following pairs of muscle-groups: Pectorals, forearm flexors, thigh abductors, and thigh adductors; for testing industrial workers the wrist flexors also were included. The reason for this was that the muscles of the forearm are probably the most used of any in the body in industrial operations, and it was thought desirable to have information concerning their strength.

The test consists of overcoming the maximum resistance of the muscle-group under examination by means of traction applied through a self-indicating spring balance. An ordinary spring balance, indicating pounds avoirdupois and preferably graduated decimally, is fitted with a strong handle attached to the frame at the upper end, and at the lower end with a loop of leather attached to the end of the "rack" which terminates the spring. The pointed indicator forms part of a "dog" or slider, which is not attached to the rack, but is capable of moving with slight friction up and down the slot. A small pin on the rack protrudes through the slot and is in contact with the upper edge of the indicator. When the pull on the spring is exerted, this pin pushes the indicator along the slot to the proper point; when the pull is ended and the tension on the spring ceases, the indicator remains at this point and its position on the scale may be read off at leisure. After the reading the indicator is pushed by the hand back to zero. When in use the loop of leather is passed over a selected point on the limb in which the muscle-group has its insertion. The procedure is outlined below.

2. Instructions for Making the Test.

General.—The individual to be tested is referred to as the subject. The persons making the test are, first, the adjuster; second, the operator.

The duties of the adjuster are to place the loop in the assigned position about the arm or leg, support it there with one hand, and, if necessary, support the arm or leg of the subject with the other hand. He gives the command "Hold back," to mark the beginning of the pull, and "Stop," to mark the end.

The operator has the handle of the balance in his right hand and the body of the balance in his left.

After the loop is adjusted the adjuster gives the command "Hold back." At this command the subject contracts with all his power the muscle-group being tested, and simultaneously the operator pulls upon the spring balance. Tension must be developed as rapidly as possible *without jerking*, and must be increased until the resistance of the subject is actually overcome. At the command "Stop," the pull is immediately discontinued. The scale is read at once and the reading is recorded by the assisting clerk. The sliding indicator of the scale must always be returned to the zero position immediately.

No muscle-group that is reported by the subject to be sore should be tested.

The most convenient order for testing the muscles is as follows:

1. Right pectoral.
2. Left pectoral.
3. Right wrist flexors.
4. Left wrist flexors.
5. Right forearm flexors.
6. Left forearm flexors.
7. Right thigh adductors.
8. Left thigh abductors.
9. Right thigh abductors.
10. Left thigh adductors.

Tests are made with the subject fully dressed.

The detailed technique of the individual tests is as follows:

Pectorals.—The subject stands at attention, with the middle of his back pressed firmly against an upright post, and with the hand of the arm that is not being tested grasping a handhold. (Fig. 1.) The arm to be tested is allowed to be limp in the hands of the adjuster until the command "Hold back," with which command the pectoral muscles are contracted as strongly as possible. The adjuster stands directly in front of the subject, facing him, and places the loop of the balance about the arm to be tested just above the elbow. With one hand he holds the loop in its position, and with the other hand grasps lightly the subject's hand or wrist. The adjuster, keeping the subject's arm straight, draws it across the subject's body as far as possible, keeping it as close to the body as can be done and still give clearance for the loop. At the command "Hold back," the subject's effort is to hold the arm from being drawn backward and downward from this position. The operator holds the spring balance in a line downward and backward from the subject's elbow in such a position that the arm as drawn back will just clear the subject's body. At the command "Hold back," the operator develops sufficient tension to draw the arm down to the side of the body. The command "Stop" must be given and the pulling discontinued before the arm has been drawn beyond the vertical line.

Wrist flexors.—The subject stands beside the upright post, with his arm flexed so as to bring the forearm horizontal and the back of the forearm against the upright post, with the arm projecting beyond the upright post to the ulnar process (Fig. 2). A folded handkerchief or towel may be interposed between the forearm and the upright. The adjuster stands directly in front of the subject's palm. With one hand he holds the subject's wrist against the upright, and with the other adjusts and holds the loop. The loop is placed so that its middle is directly over the crease at the base of the fingers. Keeping the fingers straight, the subject's hand is flexed fully at the wrist. The operator pulls at an angle just less than ninety degrees from the plane of the subject's hand. At the command "Hold back," the subject holds the wrist in extreme flexion. The command "Stop" must be given as soon as the hand begins to yield.

Forearm flexors.—The subject lies on his back on a table with his heels pressed firmly against a cleat at the end (Fig. 3). The adjuster stands at the subject's left for both flexors. His right hand holds the subject's elbow to the table. His left hand brings the subject's forearm into a position of flexion about fifteen degrees toward the shoulder from the vertical, and adjusts the loop about the wrist so that its upper edge is at the crease in the skin at the base of the hand. The operator stands at the foot of the table and exerts tension at the word of command. The command "Stop" should be given when the forearm reaches the vertical.

Thigh adductors.—The position of the subject is the same as in the test with the forearm flexors except that he presses against the cleat only with the foot of the leg that is not to be tested (Fig. 4). The adjuster stands at the foot of the table; with one hand he places the loop in the hollow just above the malleolus (an equally correct index is to have the strap just clear of the top of a man's shoe), seizes the subject's heel with the other hand, lifts the leg until the heel is just high enough to clear the toes of the other foot, and then draws the leg into extreme adduction. The foot of the leg to be tested must be kept vertical. The operator stands at the side of the table and develops tension at the word of command. The command "Stop" should be given as soon as the leg has been drawn into line with the axis of the body.

Thigh abductors.—The positions of the subject and of the adjuster are the same as in the test with the adductors. The loop is adjusted as for the adductors, but the direction of the pull is opposite to that used for those muscles. The leg to be tested is drawn out beyond the mid-line of the body to fifteen degrees, and the effort of the subject at the command "Hold back" is to prevent the operator from drawing the leg into line with the body. The command "Stop" is given just as the leg reaches the mid-line.

Calculation of total strength.—The sum of the strengths shown by the individual muscles tested constitutes in men 17.7 per cent and in women 18 per cent of the entire strength as found by this system of testing. To calculate the entire strength, therefore, the sum of the determined strengths must be multiplied by the reciprocal of 0.177 or 0.180 (5.65 or 5.55). The product thus obtained is the figure for the total strength of the individual. If, for any reason, any muscle group was omitted from the test, its strength may be assumed to be the same as that of the corresponding muscle on the other side in making the calculation of the entire strength.

3. Source of Data.

Included in this report are 5,518 tests on 305 factory workers from two manufacturing establishments, known, respectively, as factory A and factory B.[1] The first is a brass factory, engaged at the time of the investigation in making shell fuses; the second is a large automobile factory. At factory A the working period for the day shift was 10 hours in length, extending from 7 a. m. to 6 p. m., with a recess of 1 hour, from 12 m. to 1 p. m., for luncheon between the two spells; for the night shift the working period was 12 hours in length, from 6.20 p. m. to 6.40 a. m., with a recess of 20 minutes from 12 p. m. to 12.20 a. m. At factory B the working period was 8 hours in length; there were 3 shifts during the 24 hours, the morning, evening, and night shifts, with a luncheon period averaging one-half hour. Tests were made at factory A on 99 men and 116 women; at factory B, on 90 men. At both establishments repeated tests were made on the same individuals on successive days, and in a large number of instances twice daily. Where two tests were made on the same day on one person the first test was usually made about one hour after beginning work, to allow the effect of "warming up" to spend itself, and the second as soon as possible after stopping work for the day. The period covered is, for factory A, July 25 to October 5, 1917, and January 1, 1918, to March 1, 1919; for factory B, September 15, 1917, to March 2, 1918.

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[1] Factory A is the ten-hour plant and factory B the eight-hour plant referred to in the extensive report on conditions of work by Goldmark and Hopkins, "Comparison of an Eight-hour Plant and a Ten-hour Plant," Public Health Bulletin No. 106, United States Public Health Service, Washington, 1920.

OBSERVATIONS ON MEN.

1. Physical Classification of Workers.

One important field of usefulness for the data obtained by determining the average strength of each of as many workers as possible and arranging the results in a table of physical classification is found in the information thereby afforded as to the relative physical demands of different jobs. On the principle that the strength tends to become adjusted to the demands upon it one would expect to find that a group of workers all doing the same thing, would tend in course of time to show about the same strength. In other words, there would tend to be a "standard strength" for each job. As a matter of fact, precisely this tendency appears when the strengths of the male workers in the hard jobs investigated in factories A and B are tabulated. It should be noted that the easy jobs do not show a similar tendency. Nor would it be expected; for the man whose work during the earning hours is physically light is apt to take exercise, outside of working hours, as heavy as or even heavier than that of his regular job, so that the latter does not rank as the determining factor in his strength. The operations studied, on men only, with the standard strength for each, are presented in Table I. As an aid in interpreting the table the fact should be stated that the average strength of adult males as a class is between 3,500 and 3,700 pounds, according to this system of testing. In the main the grading of jobs in order of decreasing difficulty, as suggested by the strength test, agrees with a grading based altogether on empirical observation of the men at work, as is seen by a comparison of columns 3 and 4 of Table I. The empirical graduation was made by observers who were thoroughly familiar with the various operations, but were not acquainted with the results of the strength tests.

TABLE I.—*Showing that the strength of male workers in various operations tends to be in proportion to the laboriousness of the operation.*

Factory.	Operation.	Average strength.	Empirical class.	Number of workers averaged.	Number of workers tested.
A	Rivet trucking, dipping, shoveling	4,690	9	12	12
A	Swaging and drawing valves	4,550	10	11	13
B	Brazing heavy parts	4,400	9	9	12
A	Hot forging (fuse parts)	4,400	9	3	4
B	Heavy lathe work (recessing gears)	4,300	8	16	22
A	Heavy machine work	4,290	8	8	9
A	Steam room (stokers and passers)	4,220	6	4	4
B	Foundry work (ramming molds)	4,150	10	18	38
A	Heavy lathe work (turning fuse parts)	4,160	7	12	[1]15
A	Planish seat	3,940	8	3	4
A	Loading fuse rings	3,720	5	11	11
A	Tending drawn tube press	3,600	5	7	7
A	Graduate rings	3,310	6	4	4
A	Tending milling machine	3,220	5.5	11	11
B	Drilling and burring screws and bolts	3,160	4	14	14

[1] Day shift only.

In most of the hard operations there were found a few workers who not only failed to show a strength approximating the average for their group but fell below the average for workers in much easier jobs. In the belief that the poor showing of these was to be accounted for on the basis of special considerations to be treated later, they were omitted from the averages. Thirty-five hundred pounds was set as the arbitrary lower limit of inclusion. Column 5 of Table I gives the number of workers in each group whose strengths were included in calculating the averages for the groups, and column 6 the total number tested in each group. A comparison of the columns shows that in most groups the number omitted was small.

The most conspicuous difference between the graduation as determined by the strength tests and that determined by empirical observation is in the operation of ramming molds in the foundry, factory B. This operation, although manifestly belonging at or near the head of the list in terms of laboriousness, appears eighth in the column of average strengths. The operation is discussed in detail below, and features are described which may account for its unexpectedly low average strength showing. At this point it is enough to call attention to the fact that more than half of the workers tested in this operation had to be omitted from the calculation of the average because their strength fell definitely below that to be expected of normal healthy adult males engaged in manual labor. This in itself is sufficient to suggest that definite factors are operating to cut down below expectation the strength of workers at this job.

The men in the steam room, factory A, averaged higher in strength than the nature of their work would lead one to anticipate. The limited number tested probably accounts for the unexpectedly high figure, since it could easily happen that a group of four might be encountered in one operation all stronger than the general average for their work, although the necessity of working in intense heat may have something to do with the showing. The fact that so few were tested probably explains also the unduly low figure for the operation of planish seat, factory A, which was stated by all the observers to be undoubtedly more laborious than either the work in the steam room or the lathe operation of turning fuse parts, both of which appear above it in the table.

The last five operations listed in Table I all rank as light. The feature of interest about them is that they show average strengths agreeing rather closely with the general average of strength for men of all classes. By way of comparison, a group of 8 foremen from factory A showed an average strength of 3,620 pounds, and a group of 60 Army recruits from various walks of life an average of 3,680 pounds. The operation at the foot of the table, drilling and burring screws and bolts, factory B, is an extremely easy sitting operation.

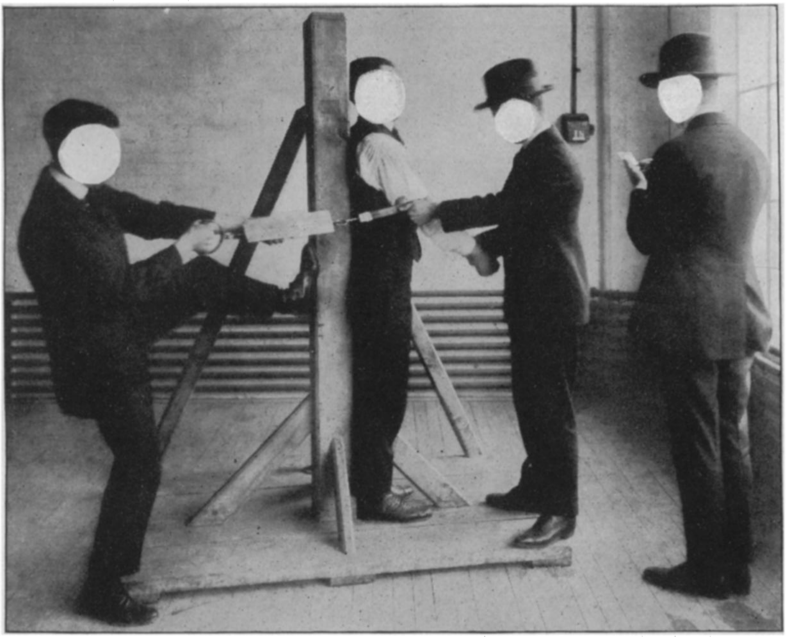

Fig. 1.—Method of measuring the strength of right pectoral muscle. Adjuster stands in front of, operator behind, subject; recorder notes down measurements.

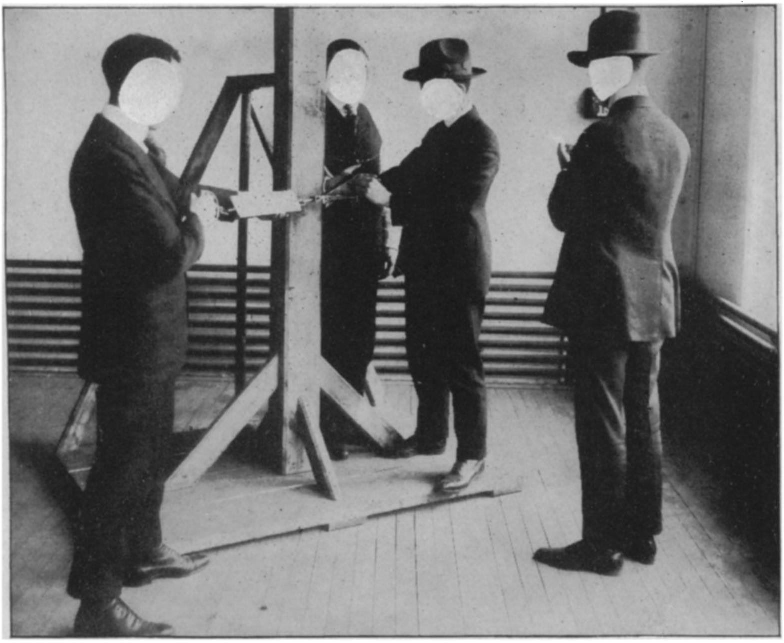

Fig. 2.—Measuring the strength of the wrist flexor.

Public Health Reports, Vol. 35, No. 33, August 13, 1920.

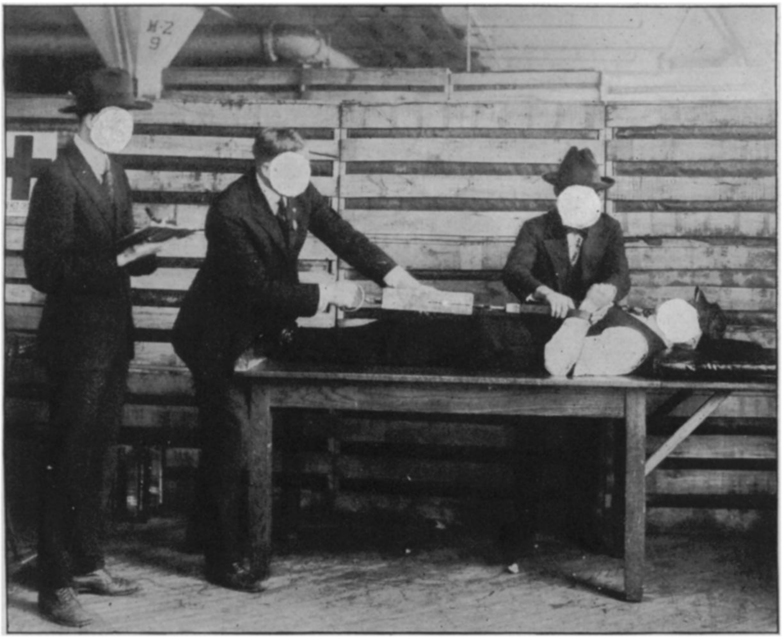

Fig. 3.—Measuring the strength of the forearm flexor.

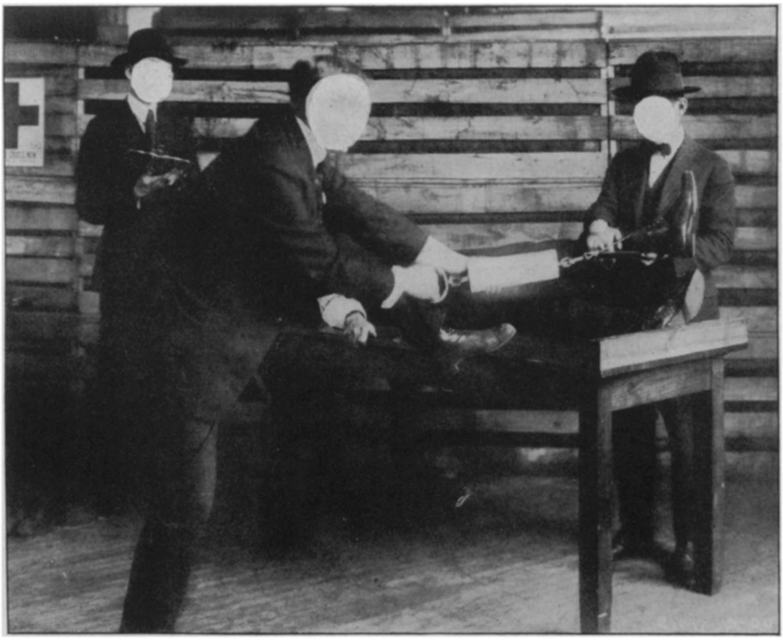

Fig. 4.—Measuring the strength of the thigh adductor.

To it are assigned, as a matter of factory policy, men with disabilities of various kinds. The low average strength showing in this group is interesting as indicating how bodily strength may be impaired by disability.

The average strengths for the various operations set down in Table I were determined as the means of groups whose individual strengths ranged on both sides of their respective means from 10 to 20 per cent. There were, furthermore, in nearly all the groups, individuals whose showing was so poor as to lead to their omission from the calculation of averages. Two questions arise in connection with the consideration of these individual strength variations: First, Are the stronger members of particular groups of more value industrially than the weaker? Second, Is there any satisfactory means of explaining the occurrence of unexpectedly weak operatives in jobs which make heavy physical demands? The prime test of industrial value is productiveness. The answer to the first of these questions is to be sought, therefore, in the production records of the workers concerned. Data are available from the records of the workers in the operation of recessing gears, heavy lathe work, factory B (Table II).

Table II.—*Showing the relation of average strength to average output. (Factory B, heavy lathe operation, recessing gears.)*

Check number of worker.	Average strength.	Average hourly output.	Check number of worker.	Average strength.	Average hourly output.
S 3122	5,280	90	S 2710	4,080	75
S 2804	5,130	89	S 3062	3,900	86
S 2796	5,000	91	S 2795	3,870	90
S 3420	4,450	84	S 3237	3,770	88
S 2781	4,450	89	S 2763	3,640	83
S 2830	4,230	81	S 3435	3,430	68
S 3075	4,210	92	S 3457	3,420	85
S 2871	4,200	91	S 3439	3,220	80
S 3202	4,180	96	S 2824	3,060	77
Mean	4,570	89	Mean	3,600	81

Average number of strength tests per individual, 19; range, 6–22.
Average number of hours per individual, 76; range, 35–94.

Eighteen out of the twenty-two whose strengths were tested yielded concurrent records of hourly and daily output. That the stronger workers tend to show a larger average output than the weaker appears by a comparison of the stronger half of the group with the weaker half. The mean hourly output for the stronger half of the group during the period covered by the study was 89 pieces, as compared with 81 for the weaker half—a difference of 10 per cent in favor of the stronger workers. Moreover, a comparison of average strength with average output, individual by individual, shows a tendency for the output to vary with the strength. The most satisfactory method of making such an individual comparison is by the calculation of the Pearson coefficient of correlation for the two sets of values. In this case the coefficient was 0.51 ± 0.118. Since this operation is one in which there is considerable room for variations in output due to skill, the correlation of strength with output is close enough to justify the conclusion that on the whole the stronger members of a group of workers are likely to prove also more valuable industrially. The second question propounded above, namely, the problem of the occurrence in laborious operations of workers whose strength is not only below the average for the job, but even below that of healthy men, seems most readily answerable on the basis of "staleness," due to persistent overexertion. It is quite conceivable that when a man embarks on a job requiring more exertion than his body at the time is fitted to perform, he either develops a degree of strength fully competent to the demand or, failing thus to develop, overuses his muscles to the point, ultimately, of actual impairment. The deficiency may be nervous rather than muscular. The strength test, depending as it does on volitional effort, does not distinguish between the nervous and muscular factors which together make up the manifestation of strength.

Observations pointing strongly toward staleness as accounting for exceptionally poor strength showings were had in connection with two operations studied at factory B. The first of these was ramming molds in the foundry, mentioned above as including a large proportion of workers whose strength tests were so poor as to be excluded from the calculation of the average strength for the operation. The work in this foundry, besides being very heavy, was carried on at the time of the investigation under conditions such as might well tend toward the impairment of physique, or at least prove unfavorable for the development of the higher-than-average strength required for the successful performance of the task. The atmosphere was filled with fumes, the light was trying, the workers were very crowded, and were subjected to extremes of heat and cold. Moreover, on account of these conditions, and perhaps of others as well, the foundry was unpopular among the workers throughout the factory. It may reasonably be assumed that the summed effect of all these influences operated to favor the onset of staleness among the workers in the department. The second operation suggestive of staleness was that of "truing" forgings by hand, factory B. This operation was not listed in Table I because, although it is among the very hard jobs of the factory, three of the four men tested who were working at this job gave exceedingly poor strength records. This work involves practically continuous gripping of a heavy hammer handle which induces muscular stiffness and even cramps. The work itself is noisy and jarring, and is, of necessity, carried on in the midst of deafening noise.

The data from the strength tests which, in conjunction with these facts about working conditions, are interpreted as indicative of staleness, are as follows: For the foundry we have, first, the actual comparison of strength between the strong and weak groups of men. The 18 men who were considered strong enough to be representative showed an average strength, as stated in Table I, of 4,150 pounds, whereas the 20 men who were too weak for inclusion in the calculation of the "standard" strength for the operation showed an average of only 2,750 pounds, two-thirds of the "standard" for the job. An additional indication of "staleness" was obtained in connection with an examination of the variability of strength distribution among the muscles in successive tests. Reference to page 1897, or to the paper of Martin and Rich (1918), shows that the muscles included in the test are assumed to constitute a definite percentage of the entire strength. This assumption is based upon studies of actual percentage distribution of the strength among the muscles included in the "complete" test of Lovett and Martin (1916) in a large series of cases.

Martin and Rich, in the paper cited above, give a table showing the percentage of the total strength contributed by each individual muscle group. From that table we obtain the following values for the muscles used in these tests: Pectoral, 2.35; wrist flexor, 1.35; forearm flexor, 2.25; thigh abductor, 1.40; thigh adductor, 1.50; totaling for each side 8.85, or for the entire test 17.7 as previously stated (p. 1900). The percentage of the total strength represented by the test strength of any individual muscle group can readily be determined by multiplying the test strength by 100 and dividing by the total strength. Applying this method to the figures for any particular individual readily gives a means of comparing his strength distribution with the ideal values proposed by Martin and Rich, or, what is of more importance in the present connection, of noting how his strength distribution varies from one test to another. Obviously one can not expect, in a test in which the subjective factors enter so markedly as in the strength test, to find the strength distribution precisely the same in test after test. Only by examination of the data from numerous experiments can an idea be had of the extent of fluctuation likely to occur.

In connection with this investigation, many workers were tested twice daily for as many as 17 successive working days. Thus, figures became available for determining the variations in strength distribution in successive tests. The method of analyzing the data was as follows: The percentage strength distribution among the muscles tested was determined for each test and the figures were tabulated, a column for each muscle. Since there were 10 muscles included in the test as here given, there were 10 such columns. The arithmetic mean of the figures in each column was found, and also the standard deviation, using the method of Pearson. The Pearson coefficient of variation (standard deviation times 100 divided by arithmetic mean) was then determined for each muscle. The average of these 10 coefficients was found and taken as representing the coefficient of variability of the individual.

To indicate the order of magnitude of the variability coefficient some actual data will be cited. Nine men, 8 of them workers in factory B, the other a college student for whom figures were available, showed coefficients of variability ranging from 9.26 to 12.9, and averaging 10.7. The average strength of these men was 4,500 pounds; the average number of tests was 30. Four of the men were workers in the foundry on the operation under consideration here as tending to induce staleness, but not in the group whose poor strength showing is looked upon as marking the presence of the condition. Four other foundry workers, all from the weak group, showed variability coefficients ranging from 13.1 to 21.3, and averaging 16. The mean strength of these workers was 2,620 pounds. So far as the data available have been analyzed, no variability coefficients higher than 13 have been found except in men suspected of staleness. The significance of the variability coefficient appears to lie in its value as an expression of "neuromuscular constancy." A low coefficient means steadiness of innervation, so that, whether the total strength be more or less, its distribution among the muscles remains about the same. A high coefficient means unsteadiness of innervation. That such unsteadiness of innervation should be a feature of staleness is merely suggested by these observations; further study will be necessary before it can be accepted as demonstrated.

In the operation of "truing" forgings, referred to above as the second job which gave evidence of inducing staleness, 4 men were tested. One of these showed an average strength of 3,970 pounds, and a variability coefficient of 9.26. The other 3 showed strengths of 2,960, 2,940, and 2,340 pounds, with variability coefficients of 12.3, 13.2, and 15.6, respectively. In view of the laborious character of the work these figures are very suggestive of the presence of the condition.

A question that is likely to arise in connection with the consideration of individuals whose strength records are far below the general average is whether these poor records are genuine. One who deliberately does less than his best necessarily makes a poor test. As showing that the poor tests here under examination were probably not made so through deliberate intent on the part of the subjects the following points are cited: A group of 5 intelligent men, all thoroughly familiar with the test, undertook to make a series of records deliberately below their actual strength, yet sufficiently like genuine records to pass muster. After considerable experimenting they not only acknowledged that it could not be done successfully, but stated that it was much easier to exert full resistance at the word of command than to resist in part. Only by keeping the idea of making a poor showing carefully in mind throughout the test was it possible to avoid putting forth full strength. Furthermore they found it impossible to remember between the testing of one muscle and of the next how much strength had been put forth, so as to make the relative strengths bear some relation to the strength distribution that actually obtains in men. The factory workmen on whom the tests were made had no particular reason for desiring to make a poor showing. A large percentage of them were foreigners who had at the best a hazy idea of what it was all about. To most of them the interval of taking the test was a welcome intermission in the day's toil, and they shared the average man's feeling of pride in being able to put forth strength on occasion. That such men, absolutely ignorant, at the beginning, of the nature or purpose of what is wanted, should be able for 30 or more tests covering more than two weeks, to maintain deliberately an inferior showing, yet throughout to keep both the total strength and the strength distribution within a reasonable margin of variation, argues a degree of intelligence quite incompatible with the industrial situation of the men themselves.

2. The Strength Test as a Criterion of Physical Condition.

It has been stated that if the strength test is a reliable indicator of physical condition the study of daily fluctuations in strength should yield valuable information as to factors affecting industrial efficiency, so far as efficiency is determined by physical condition. On the theory that the industrial efficiency, as measured in output, should bear a definite relationship to the physical condition, as expressed in strength, comparisons have been made between output records and strength records taken concurrently. In interpreting these comparisons, recognition must be had of the obvious fact that physical condition is only one of the many factors that may influence output, and, furthermore, that the strength test as a criterion of physical condition may not reflect accurately every minor variation in physical state, including, perhaps, some that might affect the output. The point must also be borne in mind that the carrying out of the strength tests constitutes a disturbance of routine which in itself may affect output.

Concurrent strength tests and output records have been made in the following departments: Heavy lathe work (turning fuse parts), factory A; heavy lathe work (recessing gears), factory B; and light sitting work (drilling and burring screws and bolts), factory B.

Output records and strength records were made readily comparable in the following manner: The mean of all the strength records of a single worker was assigned the value of 100, and his individual test records were expressed in terms of this assigned value of the mean in accordance with the formula, actual mean strength : individual strength record $= 100 : x$. In other words, the individual records were stated as percentages of the mean. In similar fashion daily output records were computed in terms of percentages of the worker's mean output record. According to this scheme, on any day on which the strength was above the average, the strength record would have a value above 100, and any day on which the strength was below the average, would have a record of less than 100. Similarly, daily output records would be above or below 100 according as they surpassed or fell short of the worker's general average.

In determining whether strength and output tend to vary in parallel fashion from day to day an extremely close numerical correlation is not to be looked for. There are definite limits to speed of machines, and interferences with output due to extraneous causes which might easily bring it about that days on which the strength record is exceptionally high should not be days of equally exceptional output; conversely, the demands of the job may often compel a fairly good output on days of poor physical condition. If any degree of numerical correlation can be demonstrated, together with additional definite, although less exact, indication that the two tend to vary together, their interdependence can justly be assumed. Three groups of workers were cited above as having concurrent output and strength records. Two of these, the lathe workers, were doing fairly heavy work, while the other group, on drilling and burring, were doing light work. It is interesting to note that the coefficients of correlation between strength and output for the workers on the two hard operations were high enough to demonstrate some degree of relationship (recessing gears, factory B, 0.27 ± 0.052, 168 cases; turning fuse parts, factory A, 0.232 ± 0.094, 46 cases); whereas the coefficient for the workers on the easy job of drilling and burring showed no relationship whatever (0.048, 187 cases).

Another method of determining whether or not parallelism is present is that of scrutinizing the day-to-day records of individual workers. For this purpose each individual's daily output records were tabulated in descending order of output, and his strength records were set opposite the output records for corresponding days.

Table III.—*Condensed summary of observations, showing tendency for high output to occur on days of good strength showing. Column 2 gives average output for days of good output; column 3 gives average strength showing for same days; column 4 gives average output for days of poor output; and column 5 gives average strength showing for same days. All figures are percentages of individual means.*

Check number of worker.	Good days.		Poor days.	
	Average output.	Average strength.	Average output.	Average strength.
Gear recessers, factory B.				
S 2796	110	105	94	88
S 3202	107	108	92	93
S 2710	113	108	93	96
S 2763	111	110	90	87
S 3015	100	109	89	88
S 2824	104	103	97	89
S 3457	108	108	93	96
S 3420	109	99	91	90
S 2781	106	98	92	93
S 2830	106	99	87	96
S 2774	106	98	91	96
S 2831	108	99	90	72
S 3062	107	95	95	86
S 2804	106	97	88	96
S 3237	111	97	89	98
S 3110	109	98	85	99
S 3439	107	87	89	99
S 3075	109	98	95	101
S 3425	109	99	89	106
S 3122	112	102	96	109
Fuse part turners, factory A.				
16652	107	105	93	91
16740	101	100	96	98
16729	101	95	94	93
16713	110	100	96	100
16888	103	98	96	105
Drillers and burrers, factory B.				
S 4146	105	110	94	94
S 4792	107	104	93	99
S 4635	104	102	94	97
S 4801	102	112	96	96
S 4611	104	100	96	89
S 4744	104	105	95	102
S 4642	104	97	94	98
S 4333	106	97	94	99
S 4747	104	104	95	105
S 4712	106	102	92	104
S 4717	104	95	97	97
S 4695	112	111	96	117
S 4171	108	100	93	106

By this plan the individual's days of best output stood at the head of the table, and his days of least output at the foot. If strength tends to vary at all in parallel manner with output, there should be indication of a similar grouping of the strength records, the upper portion of the table showing a preponderance of good records, the lower portion a preponderance of poor. Of the 25 workers in the hard operations cited above, 17, or 68 per cent, showed such a preponderance. The remaining 8 averaged as strong on the days of poor achievement as on those of good. In the easy operation of drilling and burring the tendency for high strength to occur on the days of good output was less marked. In only 6 out of 13 workers did the part of the table including the highest outputs include also a preponderance of good strength records.

In the comparisons of strength with output thus far made, the adopted criterion of strength has been the mean of the two daily tests, one taken about an hour after the beginning and the other at the end of the day's work. This median strength record would seem to represent more accurately the physical condition for the day as a whole than a single test taken near the beginning of the day. This is especially true when, as often happens, a poor showing is made at the early test and a much better one at the end of the day. The obvious deduction from such a sequence is that the initial poor test was due to something transitory in the condition of the subject which passed off during the day, and should not, therefore, be credited as establishing his status for the entire day. A low early test followed by a still lower late test is, on the other hand, indicative of poor condition throughout the day, and a high early test followed by a still higher late test of good condition throughout the day.

As further confirmation of the parallelism of strength with output it is interesting to note that in the operation of recessing gears, factory B, where there were 30 out of 168 instances in which a markedly low early test was followed by a still lower late test, in 22 the output was below the average, and in only 8 above the average, a difference of about three to one. In the same group there were 17 instances of a markedly high early test followed by a still higher late test. Thirteen of these were on days on which the output was above the average and four on days when the output was below the average, a difference in the reverse direction of more than three to one.

3. The Strength Test as Affected by External Factors.

There is a definite indication that the factors which influence the strength test as it varies from day to day act, in part at least, upon all the workers alike, provided they are in similar environment. During the investigation at factory B there were 52 days on which tests were taken on workers in two departments, or workers who had two entirely different jobs. On 43 of these days the strengths of the two groups varied together. On 9 days the strengths varied in opposite directions. Group strength was determined from day to day by first assigning to the individual records values in terms of percentages of the means, as described above (p. 1908), and then averaging the percentage strengths of all the workers within the group day by day. If the value for any day came out 100, it meant that the day was an average day; if it came out above 100, the group as a whole was stronger than the average on the day; if below 100, the group was weaker than the average. The fact that two different departments varied together, namely, were above or below the average on the same day 43 out of 52 times, shows clearly that both sets of men were responding to the same influences, so far as their strength was concerned. Moreover, not only did the two groups vary together, but the extent of departure from the average was usually approximately the same. The average difference between the strength averages for the two groups, on the 43 days on which they were both high, both low, or both median, was only 3.6 per cent.

Further corroboration of the view that physical condition is affected by external conditions which act similarly upon all the members of a group is afforded by a study of the individual records of the men who made up the group. It is clear that a mere agreement of averages is not very significant if the figures from which the averages are obtained spread over too wide a range. To illustrate: An average of 100 obtained from 12 figures, all falling between 90 and 110, is much more significant than the same average obtained from 10 figures ranging between 60 and 80 and 2 ranging between 240 and 260. The proof that the figures of a series cluster together within reasonable limits is afforded by the application to the series of the statistical methods of Pearson. The procedure involves the determination of the standard deviation, and the examination of the distribution of the figures making up the series about their mean in terms of this standard deviation. In a group of figures in which the distribution is no wider than is to be expected from the operation of the laws of probability, a distance of twice the standard deviation in the middle of the group should include slightly over two-thirds of all the figures, and a distance of six times the standard deviation should include virtually all the figures. Records of 15 days, selected at random from the series of 43 given above as consistent, were analyzed according to the method just outlined; the number of individual cases included in the record of a single day ranged from 17 to 28. On 12 of the 15 days the distribution of individual cases about the mean for the day accorded fully with the Pearson criterion; on 2 other days the spread exceeded only by a small margin the allowance; and on only 1 day was there a serious departure from the type of grouping recognized as falling within the range of probable variation. We may regard these findings as indicating clearly the operation of external factors as affecting the strength showing.

Of the various external influences which might act to modify similarly the strength of all the workers of a group, the most obvious are climatic. Records of temperature and relative humidity were obtained for most of the days on which strength tests were made. Comparisons of these with strength records have failed to show any very striking correlations between particularly high or unusually low strength records and definite climatic states. There is a slight suggestion in the data that relative humidities between 70 and 80 per cent favor high strength tests, but the correlation is not sufficiently marked to remove it from the possibility of being a matter of chance. There are fairly definite, although fragmentary, indications that very high temperatures, 30° C. (86° F.), or above, reduce the strength, especially when these temperatures are maintained over a series of days. Except for this there is nothing to suggest that temperature is a modifying factor of strength. Other possible group influences are factory light, dust, fumes, the attitude of men toward superiors, approaching holidays, pay day, etc. As indicating how these may operate it is interesting to note that the periods of greatest strength throughout the whole investigation, with one exception, occurred either on pay day or within the two-day period immediately thereafter. The fact that the members of a group vary similarly in strength from day to day has its significance in connection with the tendency reported above for strength and output to be parallel. Evidently certain days are more favorable to high output than others, and the influences which underlie the difference are such as to affect all the workers in a single environment. By analyzing these differences we shall arrive at increased understanding of the factors which determine industrial efficiency.

4. The Strength Test as a Criterion of Fatigue.

A lower strength record at the end of the working period than at the beginning is looked upon as indicating fatigue. In making this interpretation, however, one must not lose sight of the fact than an exceptionally high showing at the beginning of the shift is likely to be followed by a lower showing at the end, from the mere subsidence of the special influence that tended toward the original high test, and without, necessarily, the incidence of fatigue. Conversely, on a day on which, for extraneous reasons, a poor test was made at the beginning, improvement might be shown at the end of the working period, notwithstanding the presence of considerable fatigue. Because of these possibilities individual instances of lowered strength are to be treated as less reliable than group showings. Where a single worker regularly shows a falling-off of strength at the end of the day, or where a group of workers all show such a strength-loss on a particular day, fatigue may justly be assumed.

The observations thus far made show that, in general, strong workers fall off in strength during the working period less than do weaker workers. Leaving out of account the nature of the work done, and considering only the strength of the workers, the following figures were obtained, from men only. Because of the different conditions the data from factories A and B are treated separately.

TABLE IV.—*Showing that strong workers fall off in strength during the working period less than do weaker workers.*

Strength group.	Number in group.	Showing gain or no change.	Showing loss.	Net per cent change.
Factory A.				
Above 5,000 pounds	6	4	2	+1.10
4,500-5,000 pounds	10	8	2	+2.80
4,000-4,500 pounds	17	11	6	+ .24
3,500-4,000 pounds	13	4	9	−1.57
Less than 3,500 pounds	30	9	21	− .96
Factory B.				
Above 5,000 pounds	7	3	4	.00
4,500-5,000 pounds	5	2	3	− .21
4,000-4,500 pounds	18	4	14	−3.70
3,500-4,000 pounds	21	8	13	−4.46
Less than 3,500 pounds	39	9	30	−7.26

The strengths used as the basis of the above calculations are the averages of all the tests at the beginning of the shift for each individual, compared with the averages of all the tests at the end of the shift for the same individuals. In most cases 10 to 17 figures were available for averaging.

In addition to confirming the point that strong workers tend to show less falling-off in strength during the working day than do weaker workers, the above figures are interesting in connection with an empirical consideration of working conditions in factories A and B. The former factory is on a 10-hour basis, the latter has an 8-hour day. Notwithstanding this difference in favor of factory B, the impairing effect of the day's work upon strength is much more striking here than in factory A, where the day is 25 per cent longer. The obvious conclusion is that the men work more nearly to capacity in the factory in which the shorter day obtains.

This conclusion, which is supported by Goldmark and Hopkins (P. H. B. No. 106, pp. 18 and 74), raises the interesting question of why, if the men in the eight-hour plant are working more nearly to capacity, their output fails to show a more pronounced falling off. The facts regarding output being, as shown by Goldmark and Hopkins, that the falling off of output is markedly greater at the 10-hour plant than at the 8-hour establishment. It would appear inevitable that the increment of fatigue from hour to hour must be greater where the work is carried on at a rate more nearly approaching capacity, so that at the end of eight hours there would be a greater total fatigue. At the end of the eighth hour, then, one would expect to find the output at the 8-hour plant below the level of that for the same hour at the 10-hour plant. On the contrary, the actual output records show that the reverse is the case. What seems like the most reasonable explanation of this situation is contained in an expression of Goldmark and Hopkins (loc. cit., p. 18) as follows: "It is unmistakable that, with the shorter hours at the 8-hour plant, the *attack upon work* differs radically from that at the 10-hour plant." [Italics not in the original.] It is quite in accord with psychological experience that the attitude toward the work of the entire day should be colored by a factor of such importance as its length. As the day proceeds, the onset of subjective fatigue—disinclination to work, which may determine output quite as definitely as actual working capacity—tends to become more and more pronounced, largely as the result of the knowledge that the end of the working period is still remote; and so a falling output may supervene, even though the actual working capacity is not really impaired. Moreover, at the 8-hour plant there is definite pressure from foremen toward maintenance of output, a pressure which might go far to counteract the tendency toward slackening of output as the result of growing disinclination to work. The response to such pressure is bound to be greater where the working day is short.

From the standpoint both of employer and employee, hard work during a short day would seem to be more profitable than less effort over a longer period. If fatigue bears any relation to productiveness, as one would naturally assume, the greater loss of strength during the shorter day would be looked upon as demonstrating greater productiveness on the part of the worker. In the eyes of the employer productiveness is the chief desideratum for his workmen. The employee, likewise, can well afford to exert himself vigorously during the shorter workday for the sake of the marked advantage to him of the extra hours of leisure. The danger to be guarded against is, of course, persistent overexertion. That this actually occurs in factory B, in spite of the short day, has been suggested in an earlier paragraph, and will be referred to again.

In order to relate the degree of fatigue to the nature of the work a study has been made of the strength at the beginning and end of the shift of the workers at particular jobs. For the purpose of this study the workers in each job were subdivided into a strong group and a weak group. In most cases the subdivision was made at about 3,700 pounds strength. The operations which are associated with very great strength (swaging valves, factory A, brazing heavy parts, factory B) were subdivided at about 4,000 pounds. The easy operations of tending milling machine, factory A, and drilling and burring, factory B, were subdivided at 3,100–3,200 pounds. Table V gives the number of men in each group, the average strength, and the average percentage change in strength at the end of the shift as compared with the strength at the beginning.

TABLE V.—*Showing that hard operations cause a greater falling off in strength during the working period than do easy operations.*

Operation.	Strong group.			Weak group.		
	Number of men.	Average strength.	Per cent change.	Number of men.	Average strength.	Per cent change.
Factory A.						
Swaging valves	8	4,840	0	5	3,410	−4.60
Turning fuse parts	13	4,200	+1.7	10	3,300	− .30
Drawn tube press	3	4,220	+3.6	4	3,150	−5.30
Milling machine	5	3,520	+3.2	6	2,960	+ .68
Factory B.						
Brazing heavy parts	5	4,720	+1.0	7	3,740	− 6.00
Ramming molds	15	4,240	−4.0	23	2,870	−12.00
Recessing gears	11	4,570	−1.6	11	3,370	− 7.00
Drilling and burring	7	3,760	+5.0	7	2,560	+ 1.60

This table shows that loss of strength is more pronounced in the hard operations than in those that are easier, as well as reinforcing the previous finding that weak men show fatigue more definitely than do strong men.

The large loss of strength shown by the weak group of men engaged in ramming molds in the foundry, factory B, as well as the relatively larger number of men in the group, adds force to the suggestion previously made that this particular operation is too exhausting for all except the strongest men. These records may perhaps be looked upon as exhaustion records. If this is their true character an interesting additional point concerning recovery from exhaustion appears from further study of the data. It happened that 10 of the men in the weak group of mold rammers were under observation during the period within which fell the 5-day shut-down from January 18 to January 23, 1918, enforced by the United States Fuel Administration as a measure of fuel conservation. These 10 men showed an average improvement in strength of 7 per cent for the 3 days following the shut-down, as compared with the 3-day period immediately preceding it. Only 1 of the 10 made an actually poorer showing after the shut-down. Although no information is available as to the way in which these men spent their time during the enforced vacation, it may reasonably be assumed that they did not work as hard as when engaged in their regular occupation. The average strength of these 10 men was more than 20 per cent less than that of the strong group of mold rammers; their five days of opportunity to recover left them, therefore, in spite of a 7 per cent improvement, still much below the desirable level of strength for workers at their job. We have here a suggestion that the impairment of physique due to exhaustion may be so severe as to require considerable time for complete recovery to normal.

5. Cumulative Effect of Fatigue.

The studies thus far reported have dealt with fatigue only as indicated in a loss of strength between the beginning and the end of the day's work. It is evident, however, that the effects of fatigue are likely to hold over from one day to the next; or fatigue may be cumulative, becoming more and more pronounced from day to day. In order to test whether there is any indication that the effects of fatigue carry over from day to day a comparison was made of the strength showing immediately following days of fatigue with the strength directly after days not giving indication of fatigue. The criterion of fatigue accepted here is a poorer strength record at the end of the shift than at the beginning. When the record at the end of the day was as good as at the beginning, it was assumed that no fatigue demonstrable by this method was present; a strength difference between the first and second tests indicative of fatigue, but not exceeding 9.9 per cent, was called "mild fatigue"; a strength difference in like direction and amounting to 10 per cent or more was designated "severe fatigue." Both individual and group comparisons were made. For the group comparisons the strength-showings of all the workers were averaged for the beginning of the day, and again for the end of the day. The strength showings averaged were determined as percentages of the mean strength (p. 1908).

For the group comparisons 46 days were available. Thirteen of these were days of severe fatigue for the entire group. In other words, the group strength showing at the end of the working day was 10 per cent or more below that at the beginning of the day. The remaining 33 days showed on the part of the group either mild or no fatigue. Seventy-seven per cent (10 out of 13) of the days of severe fatigue were followed by days of poor condition, whereas only 57 per cent (19 out of 33) of the days of mild or no fatigue were followed by days of poor condition.

One hundred and fifty-three individual comparisons of the records for one day with those of the following day were made. With reference to the state of fatigue of the first day these were distributed as follows: Severe fatigue, 32; mild fatigue, 50; no fatigue, 71. Seventy-two per cent of the days of severe fatigue (23 out of 32) were followed by days of poor condition, as against 54 and 51 per cent, respectively, for the days of mild and no fatigue (27 out of 50, mild fatigue; 36 out of 71, no fatigue). These observations indicate that days of severe fatigue have a tendency to show a persistent effect in the form of poor physical condition on the day following.

A somewhat similar question that may be raised is whether there is any likelihood that a day of fatigue or a day of poor condition, although not, perhaps, itself giving evidence of fatigue, will have the effect of increasing the tendency for the day following to show fatigue. Of the 153 individual comparisons reported above, 82 showed on the first day fatigue, either mild or severe, and 71 no demonstrable fatigue. Sixty-one per cent (50 out of 82) of the days of fatigue were followed by days of fatigue, whereas only 51 per cent (36 out of 71) of the days of no fatigue were followed by days of fatigue. The effect of days of poor condition on the fatigue tendency of the following day was examined only with reference to group showings. There were 35 days of poor group condition available for study. Of these, 11 (31 per cent) were followed by days of severe fatigue, 17 (49 per cent) by days of mild fatigue, and 7 (20 per cent) by days of no fatigue. Twenty days of good group condition showed in comparison only 2 (10 per cent) followed by severe fatigue, 7 (35 per cent) followed by mild fatigue, and 11 (55 per cent) followed by no fatigue. Apparently the likelihood that persistent demonstrable fatigue will show itself is greater after days of fatigue or of poor condition than after days of no fatigue or of good condition.

6. Observations on Night Workers.

Night work was carried on at both factories, but under very different conditions. At factory A there was at the time of this investigation a 12-hour night shift working 5 nights a week, and at factory B an 8-hour night shift working 6 nights a week. The night shift at factory A worked from 6.20 p. m. to 6.40 a. m., with an intermission of 20 minutes at midnight; the night shift, sometimes called the evening shift, at factory B worked from between 2 and 4 p. m. to between 10 and 12 p. m. Some departments at factory B operated a third shift from midnight to 8 a. m., but observations on this shift were not obtained. At factory A the night shift was relatively permanent, whereas at factory B the shifts changed every two weeks. So far as the strength test shows there was no advantage of one shift over the other at factory B. Virtually all the men tested were so scheduled that about half their tests came while they were on one shift, and the other half while on the other shift. No demonstrable differences between the shifts, either with respect to total strength showing or to the tendency to fatigue were apparent. At factory A the night workers as a group made a distinctly poorer showing than the day workers on precisely similar operations. Thus in the operation of turning fuse parts, in which the standard strength for the job is given in Table I as 4,130 pounds, 8 night workers averaged only 3,540 pounds, and the strongest of the group was also the man who had commenced night work most recently. It is possible that on account of the undesirable character of night work the men in this group were primarily of poorer quality than the day workers at the same job; in fact, the foreman of the department in which the comparison was made expressed an opinion to that effect. Reference to Table V on p. 1915 shows that in any industrial operation there is likely to be a weak group, assumed to be made up, in the case of the laborious operations, of men whose strength is not suited to the physical demands of the job. Whether in this case the night shift happened to be made up of such a group, or whether the night work was itself a contributing factor to the poor strength showing, can not be established from these data by themselves. Further observations will be necessary to decide the point.

OBSERVATIONS ON WOMEN.

At factory A, where many women are employed, numerous series of strength tests were made on women. Although the tests were carried out wholly by women and in complete privacy, there was marked psychic disturbance attending the early stages of the testing on the part of practically all the subjects. Many of them were so disturbed at first that it was only by the exercise of the utmost tact that the investigators charged with the task of obtaining the observations were able to carry them on successfully. This initial disturbance did not seem to affect the values shown by the tests, for the later observations, made after complete confidence had been established and when the subjects were cooperating heartily in the investigation, rarely showed differences in strength sufficient to suggest that the early tests were invalid. A total of 116 women were tested during the period covered by this report. Twenty-five of these were tested during the early weeks of their employment in this factory and again, as far as possible, a month or more later. The others were chiefly old employees, their period of service ranging from 5 months to 7 years.

1. Job Strengths.

In order to assign standard strengths to various jobs for women in accordance with the plan used above for men, the operations were graded empirically in terms of their laboriousness, and the average strengths of the workers in the various jobs were examined to see whether they would show a correlation between strength and laboriousness of job similar to that which appears so clearly among male workers. The women on whom tests were made fall into eight groups. Three of these represent definitely laborious tasks. In descending order they are: Screw-machine operation (32 subjects), foot-press operation (12 subjects), drill operation (24 subjects). The screw-machine operation is looked upon as the most laborious to which women are assigned in factory A. It actually includes a considerable range of toilsomeness according as the pieces worked upon are large or small, but the character of the work is substantially the same in all the operations classified under this head with one exception. A grinding operation was included in this group, primarily because 6 of the 7 operatives tested had recently been transferred from screw machines to the grinding job, and it seemed reasonable to suppose that the strength of these operatives might be as much dependent on the work from which they had just been transferred as on that which they happened to be doing at the period of the tests. Less laborious than the tasks listed above are fuse assembly (9 subjects) and the dial-press operation (13 subjects). The latter ranks among the least laborious jobs studied. There are also three groups in which the actual manual work is light, but in which either constant attention or mental effort is involved. These are: Clerks (8 subjects), lacquerers (5 subjects), and bench workers (13 subjects). Table VI gives the average strengths for the 8 groups here listed.

TABLE VI.—*Showing the relation of the strength of women workers to the nature of the operation.*

Operation.	Average strength.	Average weight.
Screw machine	2,170	138
Foot press	2,020	126
Drilling	1,860	126
Fuse assembly	1,820	125
Dial press	1,660	113
Clerks	2,180	113
Lacquering	2,180	112
Bench work	1,910	120

In order to show that these averages are truly representative of the groups, the Pearson standard deviation was calculated for the two that contained a sufficient number of subjects, namely, the screw-machine group and the drilling group. In both, the standard deviation is well within the limit demanded by a probability curve. In all the groups, in fact, the figures are bunched about the mean as closely as can be expected.

Scrutiny of Table VI brings out the interesting fact that the group strength tends to vary with the laboriousness of the job so long as purely mechanical tasks are under comparison, but that when the element of mental effort enters the relationship fails to hold. Thus the two strongest groups are the clerks and lacquerers; although in terms of the muscular energy required, their jobs were among the lightest examined. That this unexpectedly high strength showing is not due to any such circumstance as the accidental choice of large and strong women for testing in these groups is shown by the very low average weights for the groups. As the table shows, the clerks averaged 113 pounds in weight and the lacquerers 112. The heaviest clerk weighed 126 pounds and the heaviest lacquerer 135. More than half of the total number in the two groups weighed not more than 110 pounds, and of these women of very light weight only one failed to make an average strength showing exceeding 2,000 pounds. In comparison with this very good showing on the part of the small women doing mental work the record shows that the average strength of all the women tested in factory A who weighed less than 111 pounds was 1,780 pounds. The obvious deduction from these figures is that the habitual doing by women of mental work reflects itself in a relatively high strength showing.

This idea is supported by the results, hitherto unpublished, of records obtained by Mosher and Martin (1918) from a group of 45 college women. This college group showed an average strength of 3,000 pounds. They did not average much heavier than the industrial group examined at factory A, and there is very little probability that any of them approached the amount of muscular effort that was expended daily by most of the factory women. In selecting the college women for testing, Mosher and Martin attempted to avoid the choice of athletes; their effort was to make the group as truly representative as possible of a good type of normally developed woman.

The marked disparity between the strength showing of college women and of factory operatives, considered in connection with the further fact that the best groups among the latter were composed of those whose tasks required mental effort, seems to indicate that among women the element of nervous control of the muscles plays a pominant part in the strength showing. Obviously in any such test as this the nervous factor ranks with the purely muscular in determining the result, but in a peculiar sense this seems to be true in women. No such disparity of strength between factory operatives and college students appears among men. Martin and Rich (1918) studied a group of college students, but obtained no higher averages than those reported in the paragraphs of this paper which deal with male industrial workers. Whether there is a difference in the neuromuscular organization of the sexes, whereby ability to innervate musculature pepends upon habitual mental alertness to a greater degree in women than in men, can not be decided on the basis of the data here furnished, although something of the sort seems to be suggested. Practically, the interpretation of "job strength" data in women demands recognition of the fact that a job requiring mental alertness will show a higher average strength than one whose demands on the muscles are actually greater but whose intellectual requirements are small.

The gradation of strength among the jobs calling for muscular effort rather than mental alertness is in accord with empirical observation of their relative laboriousness, and the averages given in Table VI may be looked upon as indicating the "standard" strengths for those particular operations. It will be noted that these figures do not show, so clearly as do the corresponding figures for male workers, a close adjustment of the strength to the physical demands of the job; nor is there any significant indication of a pronounced increase in strength to meet the demands of a very laborious operation, such as occurs rather conspicuously among men. The average strength of all the women operatives on whom tests have been made is, in round numbers, 2,000 pounds, a figure not markedly exceeded by the job strength of the screw-machine workers, 2,170 pounds, although this latter is the hardest job on which women in this factory are employed.

2. Strength Fluctuations from Day to Day.

In the section of this report dealing with the application of the strength test to male workers emphasis was laid on its usefulness as an index of general physical condition and, hence, of industrial efficiency, so far as the latter depends on physical condition. Evidence was presented that output tends to run parallel with strength. In a general way, therefore, the strength test may be taken as a criterion of efficiency, and its fluctuations from day to day as indicating variations therein. Direct evidence that output tends to run parallel to strength has not been obtained for women, since output data were not available during the period covered by the strength tests. The point has, however, been made that in women the test is peculiarly dependent on the mental state, a fact which certainly suggests the likelihood that it indicates the industrial efficiency as well. To determine which are days of low strength showing, and to determine the causative factors concerned are, therefore, problems of practical importance.

The fact has already been presented that among men the day-to-day fluctuations in strength tend to be similar in direction and extent for all the members of a group. The same tendency appears among the women here under investigation. The data have been examined only in part, but the results are clear, as follows: For a period including 65 working days the strength-records of all the women tested were tabulated, using as the expression of strength the ratio of the actual strength of the day to the average of all the tests on the individual. The results were expressed, as above with male workers, on the basis of 100, so that all days of more-than-average strength would have a value exceeding 100 and all of less-than-average strength a value below 100. The tests for each day were placed in a column by themselves, so that by running the eye down the columns one could tell immediately whether there was any tendency for the workers to vary in strength as a group; all, or nearly all, of them being of weaker-than-average, stronger-than-average, or nearly average strength on the same days. In order for a day to be accepted as showing a definite tendency it was necessary that at least two-thirds of all the records of the day be in accord. Of the 65 days so examined 49, or 75 per cent, showed such accordance, and 16, or 25 per cent, failed to show it. Of the 49 concordant days, 22 were stronger than the average, 13 approximated the average, and 14 were weaker than the average. From the standpoint of industrial efficiency the 14 days on which the individuals tested made as a group a poorer strength showing than the average are of most interest, for it is reasonable to suppose that the productiveness of the group was either less than usual on those days, or if maintained at the standard level was so maintained at the cost of exceptional strain upon the workers. By directing the attention to the conditions prevailing on days of poor group showing it should be possible to discover some of the factors which are responsible for the poor showing.

3. Fatigue.

Among women workers, as among men, a poorer strength showing at the end of the shift than at the beginning is interpreted as indicating fatigue. In making this interpretation, as has been previously suggested, single days are less reliable than series, since it may easily happen that causes unconnected with fatigue will operate occasionally to cause the strength showing at the end of the day to be poorer than at the beginning; but a consistent showing of that character may properly be looked upon as indicative of fatigue. To determine, then, whether or not any given worker gave evidence of fatigue her entire record was scrutinized. If as many as half of all the days on which she was tested both at beginning and end showed less strength at the end of the work period than at the beginning, the conclusion was drawn that her tests showed fatigue. By grouping the workers in various ways, conclusions as to the influence of different factors on fatigue become possible. The first factor to be so examined is that of the strength of the worker. When the workers are grouped wholly according to strength, without regard to the nature of their work, slight, though definite, evidence is afforded that the stronger workers are less susceptible to fatigue than the weaker. The evidence is presented in Table VII.

TABLE VII.—*Showing that the stronger women workers are less susceptible to fatigue than the weaker.*

Group strength.	Per cent of group showing fatigue.	Group strength.	Per cent of group showing fatigue.
Lbs.		*Lbs.*	
Above 2,400	55	1,600-1,800	68
2,200-2,400	60	1,400-1,600	67
2,000-2,200	67	1,200-1,400	80
1,800-2,000	61		

It will be seen here that there is, on the whole, more fatigue among the weaker than among the stronger workers. When the nature of the work is taken into account this fact appears more strikingly. Below is reproduced from Table VI the grouping of women workers used in this study, with the average strengths for the groups.

TABLE VIII.—*Showing the relation of the fatigue of women to the nature of the operation.*

Operation.	Average strength.	Per cent of all workers showing fatigue.	Strong group. Per cent of workers showing fatigue.	Weak group. Per cent of workers showing fatigue.
Screw machine	2,170	60	44	75
Foot press	2,020	66	80	50
Drilling	1,860	71	69	80
Fuse assembly	1,820	66	50	80
Dial press	1,660	42	0	62
Clerks	2,180	75	66	80
Lacquering	2,180	100	100	100
Bench work	1,910	46	50	43

To illustrate the relation of strength to fatigue, the workers in each operation were divided into a strong and a weak group. The division was so made that in general the strong and weak groups in each operation were about of equal size. As Table VIII shows, there is a distinct tendency for the weaker workers in any particular operation to indicate higher susceptibility to fatigue than the stronger workers in the same operation. Exceptions to this tendency are noted in the two operations listed as foot-press and bench work. Of the bench workers only a relatively small proportion gave indication of fatigue by the criterion here used, as column 3 of the table shows. The work was very light, as a rule, so that such fatigue as was shown might well have been due to extraneous causes. All the workers at the operation of lacquering showed fatigue, corresponding with the peculiarly trying nature of this task which combines exposure to disagreeable fumes with close concentration of attention. It is perhaps worthy of mention that the average degree of fatigue among the lacquerers, as indicated by the precentage loss of strength at the end of the work period as compared with the strength at the beginning, was just twice as great in the weak group as in the strong.

The fatiguing effect of the different operations is suggested by the figures in column 3 of Table VIII. Except for the operation of lacquering, discussed above, these figures do not show any very definite tendencies toward varying susceptibility in different jobs. They do show clearly, however, that work recognized as very light has relatively little effect in reducing the strength during the working day. This is most clearly seen in the operation listed as dial press. Less than half of the workers at this job gave evidence of fatigue by this criterion, and all who did give such indication were among the weak group.

The chief deduction to be drawn from these studies, relative to fatigue in women operatives, appears to be that close concentration of attention is more productive of fatigue than is routine manual labor, even though the latter is quite heavy. So far as the strength test is a reliable criterion, the indication is that undue fatigue is exceptional under the conditions prevailing among the women operatives employed at factory A.

SUMMARY.

1. Fields of usefulness for strength tests are seen in (*a*) physical classifications, to aid in selecting operatives for particular jobs; (*b*) as criteria of physical condition in connection with the relationship of physical condition to industrial efficiency; (*c*) as criteria of fatigue.
2. The method of testing the strength of industrial workers is described in detail.
3. Evidence is presented showing that with males laborious operations tend to develop approximately equal strength among the workers therein; in other words, there is a "standard" strength for each job. A table of the strengths associated with the various operations studied is given.
4. Male workers at very light operations are shown to have, in general, the average strength for adult males. A single group, made up of men with various disabilities and engaged in a very light sitting operation, had an average strength markedly less than the mean for healthy adult males.
5. Evidence is offered that within individual groups of males the stronger workers are likely to be more efficient industrially than the weaker.
6. The occurrence among male workers at laborious operations of individuals whose strength is much less than the standard for the job, and somewhat below the usual figure for healthy adult males, is assumed to be indicative of "staleness" due to persistent overexertion. Workers giving signs of "staleness" show greater variations in the distribution of strength among the muscles in successive tests than do normally strong operatives.
7. The question of the genuineness of poor strength showings is discussed and evidence given that it is more difficult to make deliberately an inferior test than to put forth full strength, and also that the variations in successive tests would necessarily be wider if the tests were fraudulent than are seen in the poor series here under examination.

8. That physical condition, as indicated by the strength showing, tends to bear a definite relationship to the industrial efficiency as expressed in output is shown by comparisons of day-to-day records of various male workers.

9. Observations are given showing that there is a definite tendency for the strength of all the male workers in a single environment to fluctuate similarly from day to day. The conclusion is drawn that external factors are operative in determining strength, and that these act on all the workers alike. Among these the temperature at which the work is carried on suggests itself as important. There is evidence that persistent exposure to temperatures above 30° C. (86° F.) is unfavorable to strength. Relative humidities between 70 and 80 per cent appear to favor high strength showing. Other climatic influences have not been demonstrated to be operative. There is some suggestion that psychic influences, such as the arrival of pay day, may be operative. Since strength correlates with productiveness, the analysis of these external factors promises to be significant.

10. In general, strong male workers show less fatigue than do weaker workers. This holds both for workers regardless of the nature of their work and for the strong and weak groups within particular operations.

11. Evidence is given indicating that the impairment of physique due to exhaustion may be so severe as to require considerable time of rest for recovery to normal strength.

12. There is evidence that the effects of fatigue are persistent, in that they tend to appear on the day following a day of fatigue. Severe fatigue is more likely to show this persistent effect than is mild fatigue.

13. Days of poor physical condition are more likely to be followed by days of fatigue than are days of good condition, or days on which no demonstrable fatigue appears.

14. There is no evidence that the strain of night work in an eight-hour shift, changing every two weeks, impairs physique. A permanent night shift, working 12 hours nightly 5 nights in the week, averaged 15 per cent lower in strength than the day shift doing precisely similar work; but the evidence is insufficient to decide whether or not this poorer showing was actually due to the night work.

15. Women operatives show a gradation of strength corresponding with the laboriousness of their work; the actual strength showing is, however, regularly less than would be anticipated in manual workers.

16. Women employed at tasks requiring mental alertness or close concentration make better strength showings than those engaged in routine manual toil, even though the latter be relatively heavy. A corresponding relationship is not apparent among male workers.

17. There is evidence that among women, as among men, external factors influence the strength showing. The workers in a similar environment tend, as a group, to vary in the same direction from day to day.

18. Among women, as among men, demonstrable fatigue is more manifest in weaker workers than in stronger. The most pronounced indications of fatigue are presented in an operation requiring close concentration and carried on in a disagreeable environment.

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NEW YORK LAW RELATING TO CARE OF TUBERCULOUS PATIENTS.

A New York law (chapter 900, approved May 21, 1920) provides for the listing and recommendation by the State commissioner of health of private institutions and dwellings found suitable for the board and lodging of tuberculous patients, and further provides for State aid to tuberculous patients, not bedridden, who are unable to pay either in whole or in part for such board and lodging. The law reads as follows:

SECTION 1. The health officers of any city, town, or village in the State shall have power to certify to the State department of health such private institutions or dwellings within their jurisdiction as may be suitable and desirable for the board and lodging of tuberculous patients. If such institutions and dwellings or any others be deemed by the commissioner of health of the State of New York to be suitable for such purposes, such commissioner shall, with the consent of the owners or lessees of such institutions or dwellings, make a list thereof and recommend the same for the care of tuberculous patients as hereinafter provided. The district supervisors of the State department of health shall file quarterly with the department of health of the State of New York a certificate containing a statement of the condition of such institutions or dwellings in so far as concerns sanitation, and any other matter bearing upon their suitability for the medical treatment and care of tuberculous patients.

SEC. 2. Any tuberculous patient who is a citizen and has been for one year a resident of the county in which such application is filed may make application for State aid as provided for in this act. Such patient shall file with the health officer of the village, town, or city in which he may reside a statement of his financial condition, setting forth that he requires public aid. If upon investigation by representatives of the State department of health or of a local health officer, it is found that such